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Identification and Collection of Subglacially Derived Volcanic Material on the Outwash Plains of Southern Iceland

Reports received June 2008

Project Report

Introduction:

The primary goal of this research trip was to collect samples of basaltic sand from the sub-glacial outflow plains of Iceland (Fig. 1). This sand contains a mixture of materials carried from volcanic sources beneath the extensive ice sheets of southern Iceland to coastal outflow plains. It was our hypothesis that the outflow materials would contain a certain yet unknown abundance of basaltic volcanic material that was hydrothermally altered during its residence time beneath the ice. Fig. 2 is an example Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) visible light image of the Skeidararsandur outflow plain. This extensive outwash plain is the largest example of a sub-glacial outflow system in southern Iceland and the largest braided stream network in the world (Maizels, 1993). In the fall of 1996, a major eruption at the sub-glacial volcano Grimsvotn induced a catastrophic outflood, or Jokulhlaup, that inundated the sandur with sub-glacially derived volcanic material (Russell et al. 1999). Likewise, in 1918 a higher discharge flood covered the coastal plains of Myrdalsandur as a result of a large sub-glacial volcanic eruption at Katla (Thorarinsson, 1957). These two locations and the deposits from the last major outflow events were the focus of our field work during the summer of 2007.

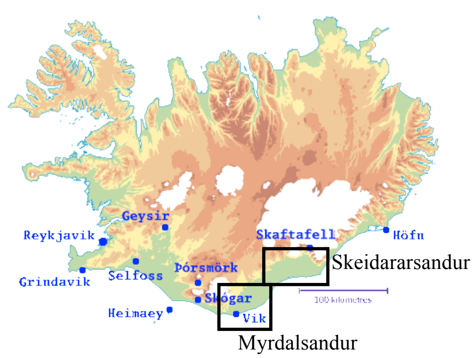


Fig 1. Location map of Skeidararsandur and Myrdalsandur in southern Iceland, the two field sites visited in this analysis.

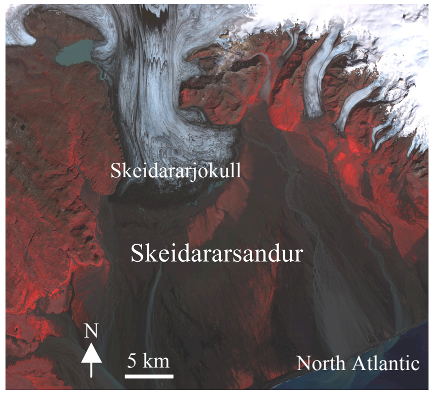


Fig. 2: ASTER visible light image of Skeidararsandur outwash plain. In this image, red is vegetation and black is the fresh basaltic sand of the sandur plain.

Significance to Astrobiology and Planetary Sciences:

Large outflow channels are not unique to Earth. Several large channels, initiating from chaotic terrain, are present near the equatorial and mid-latitude regions of Mars (Carr, 1987; Baker et al. 1992). In addition, several smaller fluvial channels have been suggested to be present on the flanks of Martian volcanic landforms including Tyrhenna Patera, Alba Patera, and Hadriaca Patera. These features do not share a similar branching morphology to terrestrial fluvial channels that form by rainfall. Rather, the proposed origin of the large Martian outflow channels is by catastrophic outflow related to melting of the planet's cryosphere by sub-surface geothermal or volcanic activity. In this regard, the Martian outflow channels can be considered process analogs to the Icelandic systems described above. Furthermore, given the dominance of basaltic style volcanism on Mars and at Iceland the two locations are compositional analogs.

An indicator of basalt-ice or basalt-water interaction is a unique mineral assemblage that is derived from the mobilization of atoms and molecules from the pristine, un-altered basaltic material. Given the presence of heat and water, basaltic glass (a common primary component of basaltic sub-glacial volcanism in Iceland) can be altered rapidly resulting in the formation of Fe-oxides, clay minerals, zeolites, silica and calcite, among others (Griffiths and Shock, 1995; Baker et al. 2000). The identification of these minerals in a basaltic system such as Mars would serve as an indicator of the past presence of water. Furthermore, their association with morphologic features on Mars indicative of catastrophic outflow would suggest a volcanically induced outflow system similar to Iceland. The possibility of subsurface hydrothermal activity on Mars has tremendous implications for the potential habitability of Mars with regards to the development and preservation of micro-organisms (Farmer, 2000). Our analysis of the outflow systems of southern Iceland, funded in part by the Lewis and Clark award, has helped to further our understanding of our ability to identify and characterize the materials derived from basalt-water interaction in a real terrestrial system.

The Field Work Methods and Results:

The primary goal of the field trip to the outflow (sandur) plains of Iceland was to identify and quantify the different lithologies present in the specific outflow deposits. First, we located ideal and safe sample site locations. These included locations present near roads and away from the distal portions of the sandur plains. The distal reaches of the Iceland sandurs contain vast stretches of un-mapped quick sand and un-drivable wet sediment. Fig. 3 displays example sample sites. At each sample site location we collected a surface sample of the upper 5 cm of sediment and took a high resolution photo. Point counting of the surface samples in the lab at Arizona State University revealed specific abundances of fresh basaltic material and altered volcanic material. High resolution photos of coarse surfaces (surfaces where samples could not be collected) were processed and lithologies determined by color matching image techniques. Fig. 4 is an example set of images from a proximal locality on Skeidararsandur. The orange clasts, which make up 6% of the scene, are clasts of palagonite, or sub-glacially altered volcanic glass. Palagonite clasts can be found within the sandur deposits throughout both outflow plains in abundances ranging from <1% - 20%.

Fig. 3: Sample sites on the sandur plains of southern Iceland. The photo on the left was taken at Skeidararsandur on the 1996 outflow surface. The photo on the right was taken at Myrdalsandur on the 1918 outflow surface.

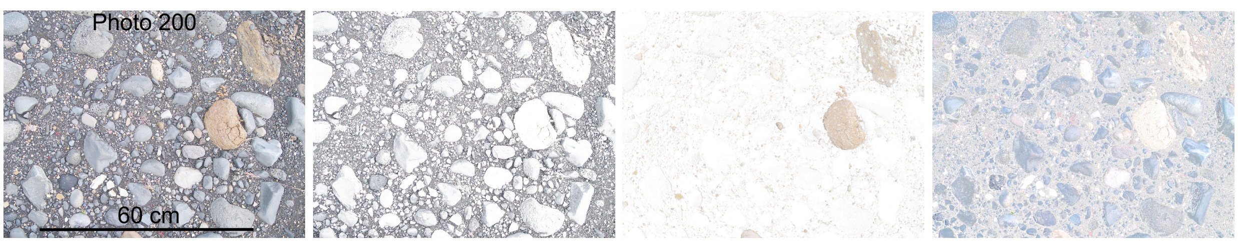


Fig. 4: Photo color sampling of a proximal surface at Skeidararsandur. At this sample site, the orange palagonite clasts make up ~ 6% of the image. These palagonite clasts are formed by The sub-glacial alteration of basaltic glass.

Through X-ray diffraction analysis, the palagonite clasts contain smectite (nontronite) clay, Fe-oxides, Ca-Na zeolites, low-quartz, pyroxene, and plagioclase. The mineral assemblage of the palagonites is consistent with low-temperature hydrothermal alteration of basaltic glass. Over 80 samples have been collected for this analysis from the sandur plains. Of these samples the majority contain a mixture of fresh basaltic glass and palagonite derived from sub-glacial alteration. In October of 2007 these mixture samples were taken to the USGS in Denver, Colorado for analysis using a visible light/short-wave infrared lab spectrometer. Fig. 5 displays the spectra obtained from four samples containing varying abundances of palagonite. Spectral absorptions from 2.2 to 2.3 microns, consistent with basaltic minerals altered by water, are present in the samples containing >5% palagonite. These spectra were then convolved to the resolution of the Earth orbiting ASTER instrument and used to map the location of alteration materials on the sandur plains. Fig. 6a shows the abundance of palagonite at each sample site location determined by point counting and photo color sampling. Fig. 6b is an ASTER image displaying the pixels that correspond with the spectral alteration signatures from 2.2 to 2.3 microns. A good correlation exists between regions of high palagonite abundance determined by field and lab techniques and the regions showing the alteration spectral signatures.

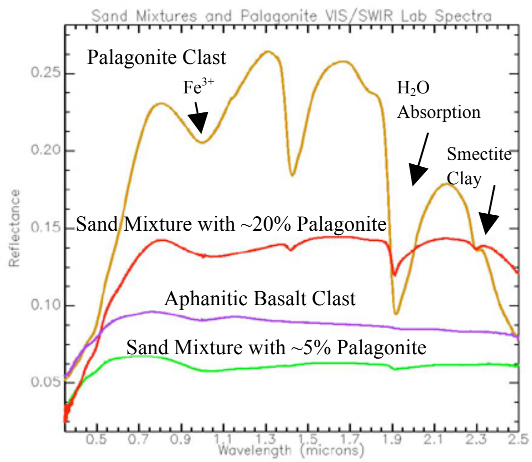
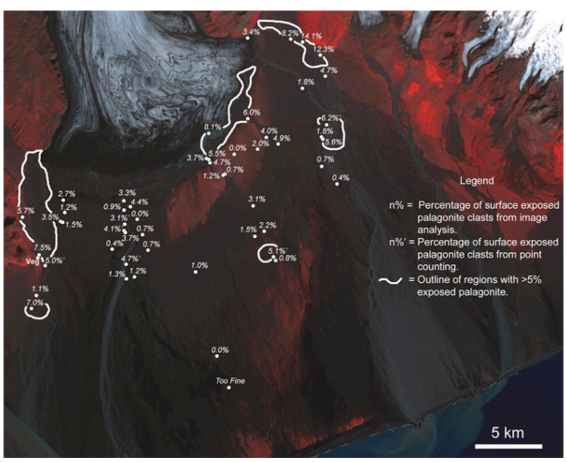
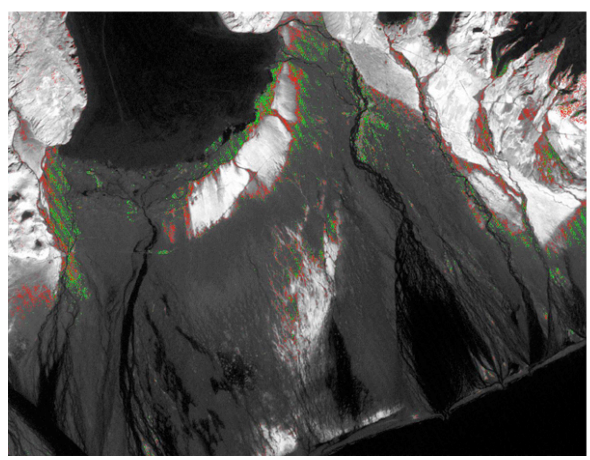


Fig. 5: Visible light and short-wave infrared spectra of mixed sand samples and a single palagonite clast on the sandur plains. Absorptions due to the presence of clays, hydrated silica, and Fe-oxides are obvious in the spectra containing abundant palagonite.



6a



6b

Fig. 6: Image 6a displays percent abundance of palagonite at sample localities throughout Skeidararsandur. Image 6b displays the location of pixels that contain spectra consistent with altered basaltic glass. The green locations represent pixels with spectral absorptions consistent with smectite clay. The red locations represent pixels with spectral absorptions consistent with hydrated silica glass.

Conclusions:

The 2007 Iceland field season was extremely productive and allowed for greater field coverage across the outflow plains. The results at this stage of our analysis seem to indicate that sub-glacially derived outflow deposits contain an abundance of palagonite ranging from <1% - 20% of the total sample. The mineral assemblage and crystallinity of the palagonites suggests intense alteration of basaltic glass derived from sub-glacial low temperature (0 – 100° C) hydrothermal conditions (Griffiths and Shock, 1995). Through use of lab spectroscopy and remote sensing imaging techniques we have been able to map the spatial location of the alteration signatures on the sandur plains. The locations of these signatures correlate with abundances of palagonite in excess of 5% suggesting that the spectral signatures of alteration materials at lower abundances are masked by the dark, energy-absorbing fresh basaltic material.

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